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MISCELLANEOUS PUBLICATION No. 340

WASHINGTON, D. C. JULY 1939

MARKET DISEASES OF FRUITS AND VEGETABLES: GRAPES AND OTHER SMALL FRUITS

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MARKET DISEASES OF FRUITS AND VEGETABLES: GRAPES AND OTHER SMALL FRUITS[1]

By Dean H. Rose, *senior physiologist*, C. O. Bratley, *associate pathologist*, and W. T. Pentzer, *physiologist, Division of Fruit and Vegetable Crops and Diseases, Bureau of Plant Industry*

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BLACKBERRIES, CURRANTS, AND DEWBERRIES

BLUE MOLD ROT, GRAY MOLD ROT

(See Grapes, Blue mold rot, p. 6 and Grapes, Gray mold rot, p. 8 and pl. 2)

RHIZOPUS ROT

(See Strawberries, Rhizopus rot, p. 21 and pl. 9)

[1] This publication is the sixth in a series designed to aid in the recognition and identification of pathological conditions of economic importance affecting fruits and vegetables in the channels of marketing, to facilitate the market inspection of these food products, and to prevent losses from such conditions. It represents an extended revision and elaboration, with the addition of colored illustrations, of a preliminary (multigraphed) Handbook of Diseases of Fruits Under Market, Storage, and Transit Conditions, prepared in 1919 by Dean H. Rose and the late O. F. Burger for the use of the food-products inspectors of the Bureau of Agricultural Economics. The material is organized on the basis of the botanical families to which the plants belong, but no botanical system is followed in arranging these families. Practical considerations make it desirable to issue the material in separate sections arranged somewhat in the order of the economic importance of the crops. The Host Index of the Fungi of North America, by A. B. Seymour, 1929, is used in the main as a guide to the nomenclature of causal fungi and the names of authorities therefor. The colored plates are reproduced from water-color paintings by L. C. C. Krieger, R. C. Steadman, Mary D. Arnold, and J. Marion Shull, of the Bureau of Plant Industry, under the direction of Dean H. Rose and D. F. Fisher, and from colored photographs prepared through the collaboration of Webster Bros., Chicago, Ill., under the direction of Dean H. Rose and the late O. F. Burger.

CRANBERRIES

FREEZING, CHILLING, AND SMOTHERING INJURY

Cranberries that have been frozen are tough and rubbery, lacking in the characteristic high luster, and often somewhat sticky. Unlike normal healthy berries, they are pink throughout rather than in the epidermis alone for the reason that following freezing the pink color diffuses from the epidermis into the whole interior structure of the berry. This structure is not, however, destroyed; the outer wall, the cross walls, and the tissues between them remain intact.

With the exception of stickiness, the symptoms just described are also found in cranberries that have been held at or close to 32° F. for 4 or 5 weeks but have not been frozen. The injury in this case is best referred to as low-temperature injury or chilling. Such injury can be avoided by holding the fruit at 36° to 40°. Temperatures higher than 40° are undesirable because of danger of loss from decay, but lower ones are not usually available in growers' warehouses, where most of the storage life of the fruit is spent. The Early Black variety seems to be more susceptible to low-temperature injury than the Searle or the Late Howe. Low-temperature injury is not common on the market because, under the present system of handling cranberries, not many are held for long periods at temperatures sufficiently low to cause it.

The term "smothering injury" is used to refer to a condition like that just described, but which is thought to be caused by holding cranberries in containers or in storage space where carbon dioxide accumulates and the oxygen supply is low. Formerly it was sometimes found in the tight barrels used for marketing cranberries. At the present time practically all of the crop is handled in quarter-barrel ventilated boxes, which furnish conditions definitely unfavorable to smothering. However, the injury is still found at times in growers' warehouses, especially if they are overloaded and are not well ventilated. Such warehouses are really only air-cooled storages, so that there is no likelihood that the condition found in them is in reality low-temperature injury except possibly in poorly managed or poorly insulated warehouses late in the storage season.

In experimental lots of cranberries showing low-temperature break-down, the percentage of berries affected has been high, and there has been very little fungus rot. This is in contrast to the condition observed in connection with so-called smothering, which usually affects a smaller proportion of the berries and is accompanied by more than the usual amount of rot (*34*, *35*).[2]

Smothering injury is usually found at or near the center of the container, whereas freezing is more likely to occur around the outside. If temperatures in storage have been such as to cause chilling injury, this condition can be expected to occur rather generally throughout the container.

FUNGUS ROTS

The rots of cranberries are numerous, but not easily distinguished from each other on casual examination even by a specialist. They differ from three other conditions previously described (p. 2) that may affect cranberries; namely, freezing injury, chilling, and smoth-

[2] Italic numbers in parentheses refer to Literature Cited, p. 24.

A, Hail injury on Niagara grapes; *B*, Ohanez (Almeria) spot, external view by transmitted light; *C*, Ohanez spot in longitudinal section; *D*, Ohanez spot in cross section; *E*, *F*, powdery mildew on gooseberry.

ering, since they may affect only a limited portion of the berry. One of them (end rot), in its final stages, reduces the berry to a water-bag condition, and most of them cause browning and disintegration of the tissues.

Decay in cranberries is favored by bruising the fruit during the operations of picking, sorting, and packing, especially if the fruit is packed while wet. Decay is also favored by high storage temperatures or by holding the fruit too long out of storage. The importance of decay is shown by the fact that recent investigations indicate a loss from this cause of about 25 percent of the total cranberry crop between the grower and the consumer.

Fungus rots can be controlled to a considerable extent by spraying thoroughly in the field with bordeaux mixture, by picking and handling the fruit with care to avoid bruising, by cooling it as quickly as possible after picking and keeping it cool until marketed.

For further details concerning cranberry fungus rots and their control, consult the following references in Literature Cited (*1*, *2*, *17*, *18*, *34*, *35*, *41*, *44*, *51*).

GOOSEBERRIES

POWDERY MILDEW

(*Sphaerotheca mors-uvae* (Schw.) Berk. and Curt.)

Powdery mildew is a serious disease of gooseberries, which affects all parts of the plant above ground. It can be recognized by the white powdery or mealy fungus growth on affected tissues, and by irregularly shaped russeted areas on diseased berries from which the fungus has disappeared (pl. 1, *E*, *F*). Berries subjected to severe attack become deformed and may even crack open and decay.

The disease occurs in practically all parts of the United States where gooseberries are grown. Recommended measures for its control are spraying with commercial lime-sulphur, fall pruning, and the removal of weeds, especially beneath the bushes, to allow free circulation of air (*10*, *17*, *18*).

GRAPES

ANTHRACNOSE

(*Gloeosporium ampelophagum* (Pass.) Sacc.)

Anthracnose of grapes is sometimes called bird's-eye rot because of the peculiar spots it produces on affected berries. These spots are usually brown at first and surrounded by a narrow zone that may vary from bright red to dark purple. As they increase in size they gradually turn gray and become somewhat sunken. The fruit finally dries up and becomes hard and wrinkled, although not as much so as in grape black rot.

The fungus also produces irregular, dark-brown, slightly sunken spots on the leaves and similar spots on the shoots. The latter, however, are often sunken and larger than those on the leaves, and they sometimes run together and form large patches or cankers.

Anthracnose is widely distributed in the United States, but seldom causes serious damage to either vines or fruit. It is rarely seen on fruit on the market.

Recommended methods of control [3] include the use of commercial lime-sulphur as a dormant spray and of bordeaux mixture during the growing season. The removal of all diseased branches or shoots during the winter is also desirable (*17*, *18*, *26*, *28*).

BLACK MEASLES

The disease known as black measles is characterized by numerous small, irregularly shaped spots, varying in color from bluish or purplish to black and scattered over any or all of the surface of the berry (pl. 2, *B*). It is apparently nonparasitic in origin; it may occur, however, on fruit from vines that show no evidence of the disease on the foliage. The name "black mildew," sometimes applied to it, is misleading and should not be used. True mildew russetting, caused by one of the fungi known as powdery mildew, is delicate, lacy, light brown, and never bluish or black.

Black measles sometimes appears in high percentage in the vineyard, but is usually culled out carefully at the packing house so that it rarely appears on the market. The varieties most commonly affected are Malaga, Emperor, Alexandria (Muscat), Burger, Carignane, and Alicante Bouschet; others of less importance commercially also show the spotting at times. The disease does not develop or spread in storage or transit.

Spraying or swabbing the pruning wounds with sodium arsenite solution while the vines are dormant, 3 or 4 weeks after pruning, has given control in some vineyards. Care must be taken to apply the solution before the buds begin to swell, and to avoid strong solutions since some vineyards have been injured by this treatment (*4*, *6*).

BLACK MOLD ROT

(*Aspergillus niger* Van Tiegh.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Black mold rot has been reported only on vinifera grapes from California. The rot is most often seen during the hot summer months and on varieties that mature during this season. All commercial varieties may be affected, but those that suffer most are Zinfandel, Alicante Bouschet, Sultanina (Thompson Seedless), Malaga, Castiza, (Red Malaga), and Burger. All of these frequently form bunches so tight that berries are broken merely by their pressure against one another in the bunch. The consequent leakage of juice furnishes a culture medium for the germination of spores of black mold and of other fungi, and for the growth of the mycelium they produce. Hence, to account for the occurrence of the rot on these varieties in the vineyard it is not necessary to assume anything more than the presence of spores of the fungus in the air. Varieties that form loose, open bunches, such as Emperor and Alexandria (Muscat), are rarely attacked by black mold except during or soon after periods of rainy weather. In table varieties, the loss on the vine of grapes that are unfit for packing may range from less than 1 percent to as much as 15 or 20 percent.

[3] PORTER, B. A., and DEMAREE, J. B. THE CONTROL OF GRAPE INSECTS AND DISEASES. U. S. Dept. Agr. Cir., 8 pp. 1936. [Mimeographed.]

A, Sun kissed condition on Malaga grapes; *B*, black measles on Malaga grapes.

Black mold rot in its commonest form is a black, watery, odorous decay occurring usually at the centers of the bunches. It is characterized chiefly by the presence of masses of spores that appear black on casual examination but are actually dark purplish brown. Because of this color and the general appearance of a nest of affected berries, the disease is often called sooty mold or smut. The mycelium is usually so scant as not to be evident except under a hand lens.

CAUSAL FACTORS

Black mold rot is caused by the fungus *Aspergillus niger*, which also attacks many other fruits, including peaches, citrus fruits, and pomegranates. In the regions where it occurs, the spores of the fungus seem to be everywhere and able to cause infection when favorable conditions are furnished. The most important of such conditions are skin breaks and leakage of juice; hence, as noted earlier, the rot occurs most often on those varieties that form tight bunches.

The spores are borne in small clusters or heads that are easily seen by the aid of a hand lens. There is no covering around the clumps of spores, as in rhizopus. The mycelium is white, but, unlike that of gray mold and rhizopus, it is almost always scant.

Black mold rot is primarily a field disease, but it is sometimes found on grapes as they reach the market. Its development is favored by high temperatures (70° to 100° F.); hence its presence on grapes on arrival at the market is probably a good indication that the rot was present when the grapes were packed and escaped the notice of the packers or that inadequate transit refrigeration was furnished.

CONTROL MEASURES

Investigations have been made relative to methods of controlling the disease in the vineyard, but no effective measures have been developed. Thinning the grapes on the bunches has been practiced by some vineyardists. For transit control, careful handling, prompt movement of shipments, and temperatures of 40° to 50° F. are fully as important with this disease as with gray mold rot, rhizopus rot, and blue mold rot. The usual sulphur dioxide fumigation is also helpful in controlling the disease in transit (*7*, *9*, *32*).

BLACK ROT

(*Guignardia bidwellii* (Ell.) Viala and Ravaz)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Black rot occurs in all the grape-growing regions of the United States except California. It is widespread in Europe, and, wherever found, is one of the most serious diseases with which grape growers have to contend. It is rarely seen on fruit on the market.

Black rot attacks all the green parts of the vine, producing (1) reddish-brown, irregularly shaped spots on the leaves; (2) small, dark-colored cankers on the canes, the fruit stems and the petioles, and veins of the leaves; and (3) a rot of the fruit. The latter appears at first as a minute blanched area that soon turns darker, becomes sunken, enlarges rapidly, and in about a week turns the whole fruit into a hard, shrivelled, black mummy. During the earlier stages the center

of the spot is light brown with a darker band encircling it (pl. 3, *B, C, D, E*). This has sometimes caused black rot spots to be mistaken for spots of anthracnose, although in the latter the center is gray rather than brown and is surrounded by a bright-red ring.

Very early in the development of the disease, numerous brown to black raised specks develop on the surface of the diseased areas (pl. 3, *D*). These are the spore-producing bodies (pycnidia) of the black rot fungus, and they give affected fruits a characteristic appearance that is of value in diagnosis.

The disease is rarely seen on fruit on the market and then only in the form of wrinkled, dried-up mummies. It is not known to develop or spread in transit.

CAUSAL FACTORS

The fungus *Guignardia bidwellii* (Ellis) Viala and Ravaz which causes black rot winters over in mummies or in diseased spots on old canes, tendrils, and leaf petioles, and spreads from these places in the spring by means of spores liberated from the fruiting bodies of the fungus. Infection and development of the disease is favored by warm, wet weather and is either checked or entirely prevented by cool, dry weather.

CONTROL MEASURES

The chief control measure recommended for black rot is spraying with bordeaux mixture; details concerning spray schedules are given in the publications cited below. It is desirable also to remove black rot mummies at picking time as completely as may be practicable without too much expense [4] (*13, 17, 18, 21 22. 26, 27, 28, 52, 53*).

BLUE MOLD ROT

(*Penicillium* sp.)

Blue mold rot is rarely found on small fruits before harvest, but it often damages them quite severely in transit and storage. On all of them it is characterized by the usual scanty growth of mold which is white at first and turns bluish green later. The mold grows along the edges of cracks in the skin or over most of the surface of affected areas. It is also characterized by a slight browning and a soft, more or less watery, mushy condition of affected tissues.

The rot is more common on grapes than on other small fruits, although it occasionally appears in rather high percentage on raspberries, blackberries, and dewberries. It is extremely rare on strawberries and so far as known does not occur on cranberries. The fungus that causes it is a weak parasite and at least in its first attack is confined to fruits crushed by too tight a pack or rough handling. Later when it becomes well established, it seems to be able to spread from affected fruits to sound ones lying in contact with them. On grapes it frequently forms a rather heavy growth on the stems and probably grows from these into the berries by way of the cap stem (pl. 4, *A*). All fruits thoroughly infected with it have a moldy smell and taste (*7, 9, 32.*)

[4] PORTER, B. A., and DEMAREE, J. B. See footnote 3.

A, Gray mold rot on Zinfandel grapes; *B*, *C*, *D*, *E*, various stages of black rot on Concord grapes.

A, Blue mold rot on black juice grapes (note moldy stems); *B*, cladosporium rot on Emperor grapes.

A, Lug bruising on Malaga grapes; *B*, shot berry of Emperor grapes; *C*, *D*, ring mildew on Malaga grapes; *E*, *F*, slip skin condition of Emperor grapes after about 3 months' storage; *G*, cracking of Flame Tokay grape (note adhering particles of sawdust); *H*, *I*, cracking of Ribier grapes.

BRUISING

Bruising injury occurs on grapes that are in contact with the lug or other container during a storage or transit period. It appears as flattened areas that vary in size according to the severity of rubbing or pressure to which the berries have been subjected (pl. 5, *A*). The affected areas sometimes show no discoloration, but on light-skinned fruit they are usually brown and on dark-skinned fruit they may be dark brown or black.

If the bruising is severe it is to that extent a factor predisposing the fruit to decay under favorable temperature conditions.

BUCKSKIN

Buckskin of grapes is a slight roughening or dulling of the skin, usually on the side of the bunch most exposed to the direct rays of the sun. It does not seem to grade into the condition known as sun kissed, but there is a possibility that the two are merely different manifestations of injury by heat and light.

Buckskin is more common on the Flame Tokay than on other varieties. So far as known it has no effect on the shipping or storage quality of the fruit. It is not known to occur on eastern grapes.

CRACKING

Grapes of the Flame Tokay, Mission, Petit Bouschet, Syrah (Petite Syrah), Ribier,[5] Castiza (Red Malaga), and Cornichon varieties sometimes show cracking at the blossom end or on the side. The cracks are rarely more than one-fourth of an inch long and one-eighth of an inch deep. In time the edges of the broken skin become dry and curl inward. Infection with various decay organisms frequently occurs, especially in storage. That caused by gray mold is the most serious, works the most rapidly, and not only destroys the grape in which infection originally occurred but spreads to others around it. Less common is infection by an olive-green mold (*Cladosporium* sp.) which appears in dry, hard pockets one-eighth to one-fourth of an inch deep, but does not seem to be at all active in causing decay (pl. 5, *G*, *H*, *I*).

Of the susceptible varieties named above, the Flame Tokay, Castiza (Red Malaga), and Ribier [5] suffer most. Nothing is known of the cause of the cracking on these or any of the other varieties. Cracking of eastern grapes (American varieties) seems to be associated with wet weather late in the summer, and there is some evidence that it can be reduced in amount by late cultivation (*22*).

DOWNY MILDEW

(*Plasmopara viticola* (Berk. and Curt.) Berl. and De Toni)

Downy mildew attacks all the tender growing parts of the vine, and in humid sections of the country it sometimes causes more loss than black rot. On young fruits it appears first as brownish spots that later become covered with the gray downy growth of the fungus. This stage of the disease is sometimes called gray rot. On older fruits the disease occurs at separate points as brown or brownish-purple patches; the skin becomes withered and eventually the whole

[5] Alphonse Lavalee is the accredited name, but the variety is grown commercially in California under the name of Ribier.

berry becomes shrunken and dark brown. This form of the disease is sometimes known as brown rot. Severe attacks cause much shelling of the fruit. The disease is rarely seen on fruit on the market.

Greenish-yellow irregular spots are produced on the upper surface of the leaves, and a thin downy fungus growth develops on the under side. Similar symptoms are produced on the young canes, leafstalks, and tendrils, which are sometimes killed by the fungus.

Spraying with bordeaux mixture seems to be the most effective control measure [6] (*17, 18, 26*).

FREEZING INJURY

The native grapes of the eastern United States or varieties developed from them, when injured by freezing, become shriveled because of rapid evaporation from the skin, and usually show a milky, opaque condition of the pulp. Normal uninjured pulp is greenish and semi-transparent. When freezing injury is severe the grapes become so watery and disintegrated that if the skin is broken all the material inside, including the thin, pulpy layer on the inner side of the skin, comes out leaving only a shell. Blue varieties undergo no color change in the skin, but red or green varieties may show a slight browning.

Vinifera varieties when injured by freezing have a dull appearance and are soft and flabby. They sometimes become wet and sticky. The stems and cap stems are often injured by temperatures that apparently have no effect on the berries. The frozen stems are at first limp and pliable, with a water-soaked or dark-green appearance, but they soon dry and become dark colored and are more susceptible to mold invasion than sound stems. When berries, injured by freezing, are pulled off the cap stem, the brush (the small bundle of fibers that extends from the cap stem into the berry) is usually found to be shorter than normal and somewhat browned.

GRAY MOLD ROT

(*Botrytis* spp.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

The fungus known as gray mold has a wide distribution in nature and attacks a great variety of fruits, among which are berries of all kinds, grapes, oranges, lemons, peaches, apples, and pears. Grapes affected with gray mold usually remain firm, and there is no marked collapse of the tissues. The fungus usually forms a nest of rot, spreading from an early affected berry to others surrounding it. The berry from which the mold has spread can usually be found at the center of the nest, well preserved in form but darkened and covered with grayish-white mycelium. Sometimes berries scattered through the bunch will be infected with gray mold, without any outward evidence of the disease. If the bunch is shaken, berries will shatter, pulling loose from the cap stem and leaving some of the flesh on it. These berries, when held to a strong light, will have a brownish cast. Probably the infection in such cases has taken place through the cap stem, while the grapes were still on the vine. Grapes exposed to several rains in the vineyard have shown this condition after several

[6] PORTER, B. A., and DEMAREE, J. B. See footnote 3.

weeks in cold storage. Another type of infection commonly observed after rains is slip skin, described on page 9.

CAUSAL FACTORS

In the early stages of the disease, the causal fungus (*Botrytis* sp.) is present in the rotted tissue but may not be evident on the outside. Later on, it grows to the surface, forming a cottony, white mass which eventually becomes gray through the production of immense numbers of spores and a slight darkening of the mycelium. It is this gray appearance (pl. 3, *A*) that gives the fungus its common name and serves to distinguish it from others commonly found on fruits.

In the vineyard it often seems to develop from the inside of the bunch outward, and in some instances apparently results from the spread of the fungus from diseased stems. More often it results from infection by spores at places where juice escapes when berries are broken by the pressure developed as the bunch grows and the berries are crowded closer together. This is especially true in varieties that form tight bunches, such as Zinfandel, Burger, and occasionally Alicante Bouschet, all of which at times are seriously damaged by the rot while the bunches are hanging on the vine. During wet, cool seasons in California, especially in the bay counties, gray mold is sometimes found causing a decay of the flowers and flower stems and a little later of the young berries. It is possible that the fungus spreads to the larger stems at this time but soon becomes dormant, only to revive on the packed fruit in transit or in storage and there cause further decay of both stems and berries.

In the vineyard and in storage gray mold and possibly other fungi sometimes form a shallow surface infection on grapes that is called slip skin (pl. 5, *E*, *F*). In such infections the mold spreads through the skin and the flesh just beneath it but does not appear on the surface. The condition usually develops after a rain and is common on late Emperors during wet autumns.

In wet weather gray mold rot is a serious disease because the fungus and its spores are more common then on vines and fruit, and spore germination is increased. When rains occur at or just before harvesttime they cause the skin of the fruit to crack and thus make it more susceptible to attack by gray mold and other decay organisms. The initial infections with gray mold usually take place in the vineyard and later develop into rot in transit and storage. In seasons when grapes are not subjected to rains or foggy weather during harvest, gray mold rot is much less common after harvest. Cool weather does not check the rot, but seems to favor it because gray mold is able to grow at temperatures that seriously limit the growth of other fungi that may be present.

In transit and storage, as in the field, conditions most directly affecting the development and spread of gray mold rot are water on the fruit and an easy entrance through the skin. Water may be present on fruit picked and loaded during times of heavy rain or dew, or it may condense there because of a moist atmosphere and fluctuations in temperatures in the car or storage room. An easy entrance into the fruit may be furnished by injuries resulting from careless handling or too much handling prior to loading, from rough handling

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in transit, or from shifting and breakage due to improper stowing of the packages. While there is danger of loss from gray mold rot even when injuries are few, since the fungus is able to penetrate the uninjured skin of most fruits, the danger is much greater if injuries are numerous. A product that has suffered from careless handling of any sort is much more subject to attack than one that has been carefully handled at every step.

Temperature is also of definite and direct significance. Gray mold rot develops fairly fast in the field during cool weather; in transit and storage its growth is not entirely checked by the temperatures ordinarily found in refrigerator cars. It is in fact able to grow and cause some decay at 32° F., although its progress at that temperature is much slower than at higher ones. Growth of the fungus is most rapid at about 77° and falls off as the temperature is raised above that point, the rate of decrease being greatest above 86°.

CONTROL MEASURES

Control of gray mold rot in transit depends on careful handling methods, good refrigeration (40° to 45° F.), and prompt movement of all shipments from field to market. For control in storage the temperature should not be higher than 32° and for storage varieties of grapes might well be 1° or 2° lower, since the freezing point of these varieties averages about 25°, varying considerably with the sugar content. Fumigation with sulphur dioxide is desirable.

Pruning and trellising methods that permit the grapes to dry rapidly after rain or foggy weather will probably be helpful in reducing infection of the fruit in the vineyard (*7*, *9*, *12*, *32*, *47*).

GREEN MOLD ROT

(Species of *Cladosporium*, *Alternaria*, and *Hormodendrum*)

On grapes of the Emperor and other storage varieties held in cold storage for 3 or 4 months, a black firm decay involving one side of the berry is occasionally found. The decay is not definitely sunken, but the grape is flattened or wrinkled on the affected side. The surface of the lesion is usually smooth and unbroken, although occasionally it is covered with a sparse growth of gray-green fungus. The decay is shallow, usually not extending to the seeds. The affected tissue is firmly attached to the skin and can be easily removed with it. It is dark and firm in the center, becoming milky and gelatinous toward the edges.

Nothing is known concerning factors influencing the decay. Probably the organisms causing it gain entrance through injuries received during harvesting or fumigation. It develops slowly at a storage temperature of 32° F.

HAIL INJURY

Grapes that have been torn by hail are of course easily recognized if examined a day or two after the injury occurred. There is, however, another form of the injury that may at times be confused with internal browning (p. 11). This occurs when grapes are bruised by hailstones but in such a way that the skin is not broken. It is characterized by a browning of the flesh on one side of the fruit instead of in a zone completely surrounding the seeds, as in internal

browning. As seen from the outside, it appears merely as a darker spot on the side of the berry. No investigation has been made of the history of such injured places during the marketing process, but there is little doubt that the skin over them is weakened and makes the fruit more susceptible to attack by decay organisms (pl. 1, *A*).

HEAT INJURY

During periods of high temperature, especially those that come in midsummer, grapes in California sometimes suffer serious damage known as heat injury. In its commonest form this injury consists of definite sunburn and even complete killing and drying up of part or all of the fruit in bunches at the top of the vine or in places fully exposed to the sun.

In another form of heat injury frequently seen, the grapes become wilted or softened, and the flabby wilted condition often remains permanent. In certain vineyards known to have suffered from high temperatures, Malagas are sometimes found to be permanently collapsed like a leaky rubber ball. These when cut show cavities in the pulp around the seed.

INTERNAL BROWNING

In California, some grapes of the Malaga variety when seen from the outside sometimes appear slightly darker than other berries in the bunch. When cut, these are found to have a brownish discoloration in the flesh surrounding the seeds and extending to within about one-sixteenth of an inch of the skin. In location and general appearance, the discoloration is roughly analogous to that often found in apples affected with internal browning. It does not seem to be due to decay organisms and is not followed by decay. No other variety than the Malaga has been found affected and nothing is known of the cause.

OHANEZ SPOT

The Ohanez variety of grapes (usually known to growers and receivers as Almeria) sometimes shows a spotting that does not occur on any other variety except possibly Olivette de Vendemain. The spots may occur at any place on the surface of the grape or in any part of the flesh. Those on the surface are faint purple or gray and slightly sunken; those in the flesh are brown and they sometimes underlie a sunken area on the surface. Both kinds resemble drought injury in plums and prunes and can be seen more distinctly if affected fruits are held between the observer and a strong light. Under such conditions or if observed in longitudinal sections, the spots are seen to be associated with a brown discoloration of the vascular bundles (pl. 1, *B*, *C*, *D*).

The cause of the spots is not known. They are not associated with decay of any sort, and there is no evidence that they increase in number or size in transit or storage. Nothing is known of methods of control.

POWDERY MILDEW

(*Uncinula necator* (Schw.) Burr.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Powdery mildew occurs in practically all parts of the United States where grapes are grown, but it appears on the market almost exclu-

sively on grapes from California. European or vinifera varieties are much more susceptible than those native to the United States. The most susceptible of the commercially important varieties are the Flame Tokay, Carignane, Alexandria (Muscat), Olivette de Vendemain, and Petite Syrah. The more resistant commercial varieties are Alicante Bouschet, Petit Bouschet, and Mataro. However, all vinifera varieties may be injured severely if weather conditions are favorable for the growth of the fungus and no effort is made to control the disease (*18*).

Powdery mildew is a fungus that attacks all green parts of the vine, appearing as a white powdery growth consisting mainly of spores mixed with or lying upon the delicate threads of the fungus. It may cause any or all of the following: (1) Spotting and discoloration of all parts affected, (2) dwarfing, cracking, and shelling of the fruit, and (3) dwarfing of both canes and leaves. The discoloration on the berries is a light-brown, lacy russeting which is easily distinguishable from the solid brown patches produced by sunburn and from the small black or purplish-brown spots characteristic of black measles (pl. 10, *B*). On the stems of the bunches, mildew spots are gray at first, then turn brown, and in the latter condition are often called dead mildew by receivers on the market. From the central brown patch on the stems, fine, brown, weblike lines extend in a more or less radiating pattern, eventually forming spots an inch long or even longer, since several infections may run together. Stems of normal healthy bunches when picked and held for some time turn brown, but the general opinion among growers and shippers is that mildewed areas under like circumstances turn to a much darker brown. The claim is also made that mildewed stems are more brittle than normal, healthy stems. So far as known, however, there is no scientific evidence to support this contention.

A distinct growth of white mold in a bunch of grapes in the packing house or on the market is a sign not of mildew but of one or more of the three common rot fungi (blue mold, gray mold, and rhizopus) which probably entered through cracks in the skin or as secondary infection following mildew injury. Diagnosis of mildew without the aid of a microscope must depend on the presence or absence of the brown weblike or lacy russeting and the white mealy growth.

Claims have been made at various times that mildew leads to decay in transit. It is known to occur on the stems of the bunches, and while sulphuring in the vineyard (in California) and careful culling at the packing house do much to keep mildew out of the packed fruit, there is always a possibility that in a mildew season a small percentage of bunches carrying mildew on the stems may go into the pack. However, even under such conditions there probably is none of the fungus growth on the berries at that time. There is no evidence that the mildew develops further after the fruit leaves the vineyard, or that it predisposes the fruit to decay except possibly by weakening the skin so that cracks are more common and decay fungi find easier entrance. Mildew russeting as seen on the market is usually mild, and such cracks as can be found are very small and have healed over.

CAUSAL FACTORS

The fungus *Uncinula necator*, known as powdery mildew, produces two kinds of spores: (1) Summer spores (conidia) which are borne on numerous short branches of the mycelium and which as they lie in

masses on the scant mycelium produce the white powdery appearance already mentioned, and are the means by which the fungus is spread during the growing season; and (2) winter or resting spores (ascospores) produced in the fall in black bodies (perithecia), that are barely visible to the naked eye. The spores produced in these perithecia are the chief means by which the fungus is carried over the winter, although in the hot, interior valleys of California they sometimes seem to be replaced in this function by the mycelium.

The fungus is favored by shade and moisture, but requires less of the latter than do most of the other fungi that cause grape diseases. It does not grow well in a very dry atmosphere, however, hence it is seen less commonly in the interior valleys of California than along the coast.

CONTROL MEASURES

On vinifera varieties, the disease can usually be controlled by one to six applications of sulphur dust, the number and time depending on locality, weather, variety, and the exposure of the vine. The larger number will be necessary with susceptible varieties in warm moist seasons or in districts that have a moist climate. In dry seasons or in districts where the climate is regularly dry, a smaller number of sulphurings (sometimes only two) will be sufficient. Under conditions most favorable to the growth of mildew, sulphuring should be done (1) in the spring when the vine shoots are 6 to 8 inches long, again when they are 12 to 18 inches long, and a third time when they are 2 to 3 feet long; (2) in early summer; and (3) in late summer, whenever mildew is found on any vine.

Spraying with bordeaux mixture has been found to give satisfactory control of the disease on American grape varieties in New York. Sulphur dust causes considerable injury to these varieties and should not be used on them. This is not usually a serious matter, however, since, as stated above, the disease is much less common on them than on European varieties (*3*, *5*, *7*, *13*, *15*, *17*, *18*, *19*).[7] [8]

RAIN DAMAGE

European or vinifera grapes in California differ from American varieties grown there or throughout the East in being susceptible to more or less serious damage by rain during the picking season. Practically all varieties are affected, but those that suffer most are Alexandria (Muscat), Sultanina (Thompson Seedless), and Gros Colman. The varieties most commonly subjected to rains are the late ones, such as Emperor and Ohanez, and while they do not show the skin cracking that develops on the Sultanina and Alexandria (Muscat) varieties, fungi gain entrance because of the rain, and secondary damage is done that is sometimes serious.

The injury consists of (1) loosening of the grape from the cap stem; and (2) cracking on the side or at the stem end, the latter taking the form of partial or complete circles around the cap stem. Both of these make it easier for decay fungi to enter, and in conjunction with the greater abundance of such organisms because of the rain, bring about a third sign of rain damage, namely, mold growth and decay on the fruit even in the vineyard. However, such a condition

[7] PORTER, B. A., and DEMAREE, J. B. See footnote3 .

[8] DURUZ, W. P., and OWENS, C. E. POWDERY MILDEW OF GRAPE AND ITS CONTROL. Oreg. Agr. Expt. Sta. Circ. Information 123, 4 pp. 1935. (Mimeographed.)

does not always mean that grapes showing it have been rained on. It frequently occurs in shipments made up of grapes picked long before the rains began. Hence the recognition of it as due to rain must always depend (1) on there having been rain, (2) on the presence of the other symptoms described, and (3) on the absence of conditions that might have brought it about without rain having fallen, such as dew in the vineyard or the condensation of moisture on the fruit after it is placed in the car.

RAISINING

The production of raisins by drying is a regular procedure in the marketing of a large part of the crop from vinifera vines in California and other parts of the world. But the presence of raisining in fresh grapes shipped for table use is undesirable, since it damages their appearance. It is also undesirable in juice grapes if the juice is to be pressed from the grapes for wine making, because it reduces the quantity of juice obtainable. On the other hand, if the grapes are crushed and then allowed to ferment, pomace and all, some raisined fruit is desirable because of its high sugar content.

Four stages can usually be recognized in bunches where raisining occurs: (1) Plump, fresh grapes that have normal color; (2) grapes that are still plump but have begun to turn brown (pl. 6, *B*); (3) grapes that are definitely brown all over, have lost moisture, and are becoming flabby and soft; and (4) those that have progressed far enough in the drying process to have assumed the color, taste, and physical condition of raisins (pl. 6, *A;* 7, *A*).

White or green varieties darken as they dry, and when found in the soft, flabby condition are sometimes thought to be decayed. A correct diagnosis is easily made by tasting a few affected berries.

Raisining may be due to extremely hot weather during the harvest season or to delay in removing the crop from the vines. Whether or not it can develop in storage or transit is a question to which no definite answer can be made. In a test with Alexandria (Muscat) grapes at shipping point in California in 1934 no darkening was found in either green or amber fruit after holding it in storage at 50° F. for 10 days and then at room temperature for 10 days more. In transportation tests made the following year 7 percent of the undiscolored berries in one test and 11 percent in another became noticeably darkened after 14 days in an iced refrigerator car. No increase was noted in the percentage of true raisins, but evidence was obtained that grapes showing some darkening when loaded had a greater tendency to continue to darken in transit than those that were normal in color when loaded. No data are available for other varieties grown in California.

RHIZOPUS ROT

(See Strawberries: Rhizopus Rot, p. 21)

RING MILDEW

Malaga and Alexandria (Muscat) grapes grown in California occasionally show a brown spotting which is known as ring mildew or fingerprint mildew (pl. 5, *C, D*). No evidence has been obtained that the spotting is caused by the grape powdery mildew, or indeed by any other organism; yet it keeps its name and has the appearance of being

A, Raisining, late stage, on Alexandria (Muscat) grapes; *B*, raisining, early stage, on Alexandria grapes.

A, Raisining, late stage, on Zinfandel grapes; *B*, sunburn on Zinfandel grapes.

more than a mere russet brought about by any mechanical or chemical agent.

The spotting is well described by its various names. It is entirely superficial and may occur anywhere on the berry, but is usually found at or near the blossom end. Bunches with more than half a dozen of the spotted berries are rare, and there are vineyards in which the blemish does not seem to occur at all.

SCARRING

Several different kinds of marks or spots occur on grapes which are well described by the term "scarring." Among them are the following:

1. Cane or leaf rubs, that are brown to black and somewhat elongated; they usually have a smooth surface (pl. 10, *C*).
2. Spots caused by hail injury when the fruit was young. These are tan-colored, have a roughened surface, and are generally depressed below the uninjured skin around them.
3. Thrips injury that occurs as russeted areas, sometimes involving the entire surface of the berry.
4. Small, circular, smooth, brown spots or flecking in the skin of Sultanina and occasionally of Malaga. The cause of these is unknown.

The spotting known as black measles is described on page 4.

Scarring of any kind detracts from the appearance of the fruit, but, so far as known, none of the types predisposes the fruit to decay.

SHOT BERRY

The condition known as shot berry (pl. 5, *B*), seen most often in Sultanina, Malaga, Muscat, and Emperor grapes, is characterized by small, poorly developed berries scattered among the normal-sized berries of the bunch. In varieties that normally produce seeds these small berries are usually seedless.

The condition is frequently seen in fruit as it comes to the packing house, but does not often appear on the market because affected berries are trimmed out in packing. It is not associated with decay of any kind, either of the stems or of the berries.

Shot berry is apparently due chiefly to poor pollination, though the causes that bring this about are either not known or are poorly understood.

Little is known of methods of control. The most definite recommendations that can be made are that all vineyard practices should be such as to keep the vines in a vigorous, healthy condition. It is advisable to prevent overbearing.

SULPHUR DIOXIDE INJURY

In California, grapes are frequently fumigated with sulphur dioxide to prevent the development of decay. The treatment may be applied to fruit in refrigerator cars, in cold-storage rooms, or in small rooms built at packing houses for the purpose. Three methods are in common use. One of these consists in burning sulphur in shallow pans in the car or other space where the grapes are held. In the other two methods, sulphur dioxide from cylinders of the liquefied gas is either introduced full strength into the car or storage room and there allowed to mix with air, or it is first mixed with air and the mixture is introduced into the space containing the fruit.

When fumigation is done in cars, more gas is required if the bunkers contain ice than if they do not.

In addition to the methods just described there is a fourth, developed in recent years, that involves the use of sodium acid sulphite, a compound that releases sulphur dioxide slowly when brought in contact with moist air. Five grams of this chemical, sprinkled in the paper pad used at the bottom of display lugs or mixed with the sawdust sometimes used as a packing medium, has generally given as satisfactory protection against mold and decay as any one of the other treatments. It is sometimes used in addition to the other treatments.

If too much of the sulphite is used, or if too much gas is applied in using the commoner fumigation methods, or if such fumigation is continued too long, grapes may be so injured as to seriously impair their market value. If grapes are weak, or immature, or very warm they absorb the gas more readily, and are therefore more likely to be injured by fumigation than if they are firm, mature, or cold. Some varieties take up the gas faster than others and consequently are more easily injured. Fairly resistant varieties are Ribier [9] and Alicante Bouschet; Castiza (Red Malaga) and Emperor are quite susceptible to the injury.

The injury is caused by the sulphur dioxide which the grapes absorb. It may occur in two fairly distinct forms: (1) A bleaching or decolorization of the skin of the fruit, usually most pronounced at or near the stem end or around cracks in the skin (sometimes in isolated circular spots) but often extending over the whole surface of the berry (pl. 8, *C*); and (2) a deadening or dulling of the color but without definite bleaching. This form of the injury has been observed chiefly in Emperors (pl. 8, *A*). Grapes severely injured by sulphur dioxide sometimes become wet and sticky because of the killing of the skin and the subsequent leakage of juice.

If the injury and bleaching occur only in a narrow zone at the stem end, that part of the skin and the underlying flesh may eventually dry out and collapse, thus forming a small depression or cup, which at first might be mistaken for the beginning of decay (pl. 8, *B*). However, the skin over such a depression is decolorized, not discolored, and there is no odor or taste of decay. The condition described is sometimes referred to as sinking of the cap stems.

In mild injury the coloring matter of the skin is not destroyed, or so little is destroyed that there is no perceptible color change. In severe injury colored varieties may be bleached and white ones assume a grayish cast. The normal color does not return even though the fruit is removed from the car or other storage space and exposed for several days to the air. Under warm temperatures, injured grapes usually develop a brown or dead color, probably caused by oxidation of injured tissues. Badly injured grapes usually have a distinctly disagreeable, astringent flavor.

The injury is more likely to occur when the sulphur dioxide is produced by the burning of sulphur than when it is obtained from cylinders of the liquefied gas, because it is much more difficult in the former case to regulate the distribution of the gas around the fruit. Furthermore, the burning of sulphur raises the temperature in the car and this in itself causes the fruit to absorb the gas more rapidly.

[9] See footnote 5, p. 7.

A, Sulphur dioxide injury on upper part of a bunch of Emperor grapes (color of lower part is normal); *B*, sulphur dioxide injury on Emperor grapes, appearing as sunken cap stems; *C*, sulphur dioxide injury on Emperor grapes, appearing as a sharply delimited, decolorized area at the stem end.

When grapes are fumigated with sulphur dioxide, bleaching around the cap stems or at cracks in the skin is sometimes observed within half an hour after the gas is released in the storage room or car. There may also be a uniform fading of the color within that time. Browning or marked dulling of the color develops later, probably because of the time required for oxidation to take place in the injured tissues. It is usually noticeable within 24 hours after the grapes have been removed from a cool car or a storage room.

Injury produced by sodium bisulphite may not develop for about 24 hours, because time is required for sulphur dioxide to accumulate in the containers to a concentration that will cause injury. The rate at which this accumulation occurs depends on the tightness of the container or the room, the velocity of air movement around the fruit, and the quantity of sodium bisulphite used (*20*, *23*, *24*, *25*, *48*, *49*).

SULPHUR INJURY

When grapes are dusted with sulphur to control powdery mildew, severe injury to the skin sometimes results. This appears on the side of the berry exposed to the sun as smooth brown areas, varying in size from about one-sixteenth to more than one-half inch across. The spots are superficial and do not seem to lead to decay. Most packing-house managers try to keep them out of the table pack, because of their effect on the appearance and consequently on the market value of the fruit. They are of no significance in juice stock.

Prevention of such injury probably depends mostly on sulphuring when the temperature is below 110° F., since field tests have shown that sulphuring when the temperature is higher than about 110° is dangerous to both leaves and fruit. Even distribution of sulphur is also recommended to prevent injury.

SUN KISSED

The condition known as sun kissed or sun kiss on grapes consists of tan to sometimes dark-brown spots that vary in size from one-fourth inch in diameter to areas that cover fully half the surface of the berry (pl. 27, *A*). Under a hand lens these areas show a delicate streaking lengthwise of the berry, in contrast to the lacy appearance of mildew spots. They are largest and darkest on bunches most exposed to the sun, that is, at the top of the vine or on the southwest side, yet they can be found on any part of the vine where bunches are so located that the sun's rays strike them.

The condition seems to be due to injury by sunlight or sun heat, or both, for it is frequently possible, in bunches at the top of the vine, to find all stages from the mildest sun kiss to the most definitely marked sunburn (pl. 7, *B*) (p. 11) and even berries that are shriveled and dead.

Sun kiss, though most common on Malaga, is sometimes found on Alexandria (Muscat), Ohanez, Emperor, and Olivette de Vendemain. It apparently does not lead to decay during the ordinary transit period, except where the browning is severe and the skin shrivels and cracks. If present in shipments to a greater extent than about 3 or 4 percent it is considered objectionable by many receivers on the market. Possible reasons for this discrimination against it are that it is held to be a serious blemish on the fruit, or that since it usually appears in

greater percentage late in the season it is believed by receivers to indicate overmaturity.

WATER BERRY

Grapes affected with water berry are soft and watery and so low in sugar content that the hydrometer test on bunches showing a large proportion of them may run 5 to 10 percent below the usual figure for the variety. They are easily cracked or crushed by the handling incident to picking and packing, and are therefore thought to produce conditions favorable to decay during the process of marketing. Affected berries may occur anywhere in the bunch but are found most frequently at or near the lower end of the bunch or at the tips of the laterals of the bunch. The varieties most often affected are Malaga, Sultanina, Emperor, and Flame Tokay.

A condition occurring in Carignanes and sometimes referred to as overmaturity bears some resemblance to water berry. Affected berries are soft and flabby and when pulled from the bunch and squeezed their contents are found to be in an almost liquid condition that suggests decay. However, such berries have no particularly disagreeable taste although they are usually low in sugar content.

The condition known as red berry in the Zinfandel, Cornichon, Mission, and other black varieties shows all the characteristics described for water berry except that affected grapes have a dull-red color instead of the black or blue black that is normal for the variety. Red berry is easily recognizable in the vineyard.

The cause of grapes becoming watery and failing to develop into firm crisp berries is unknown. Growers have observed, however, that firmer, better storage grapes are produced if the vines are not too heavily loaded. In growing Sultanina grapes, firmer, larger, and more attractive fruit can be obtained by thinning the bunches on the vine, and the berries on the bunch, removing the tips of the bunches where most water berry occurs, and by girdling the canes upon which the fruit is borne.

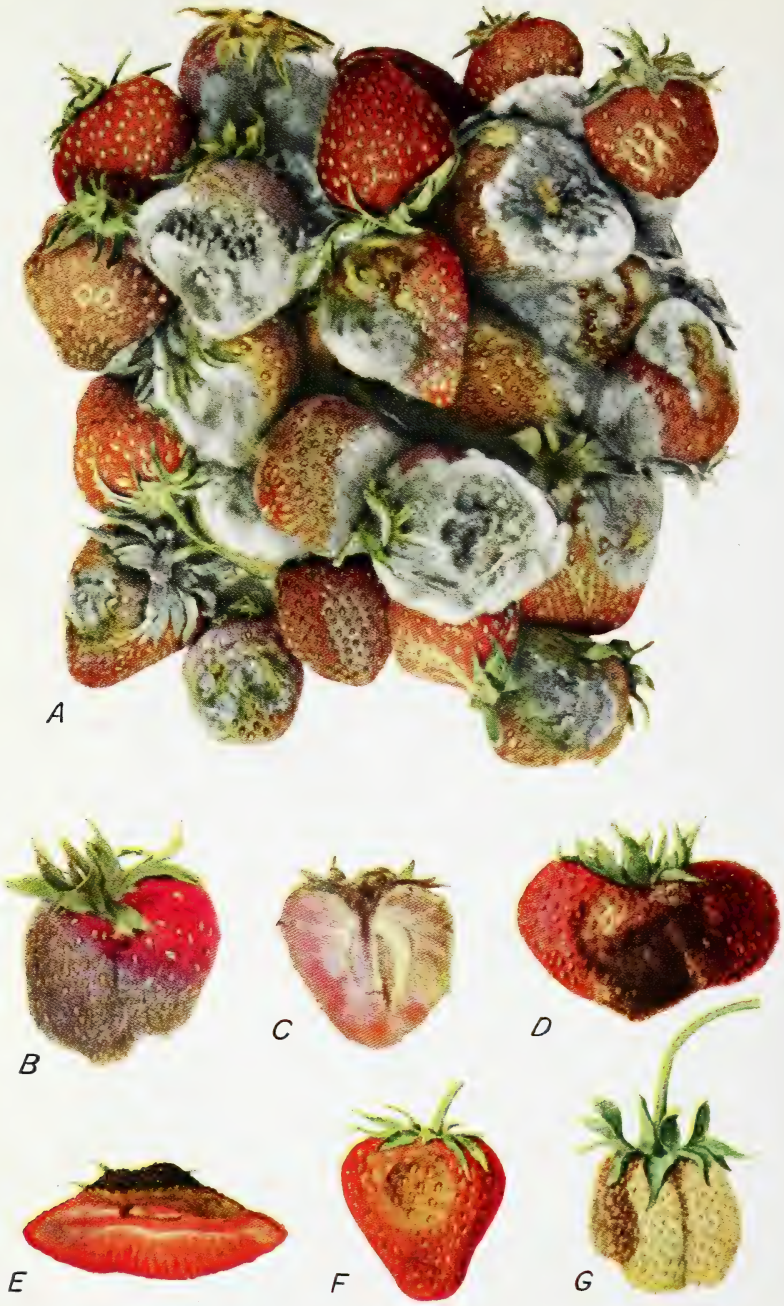
RASPBERRIES

MOLD

(*Cladosporium* sp.)

Raspberries sometimes arrive on the market partly overgrown with an olive to olive-green mold. The mold is most abundant on the inside or cup of the berry but may also occur on the outside. It causes little or no decay of the flesh, either in laboratory tests or in commercial shipments, but, of course, renders affected fruit unfit for consumption.

Nothing is known of when or how infection occurs. Recommendations for control must therefore be based on the assumption that this fungus, like others occurring on fruits, grows more slowly at low than at high temperatures and requires some time to become established. For fungi that behave in this way, control depends to a large extent on careful handling, expeditious packing and shipment, and temperatures of 40° to 45° F. en route to market.



A, Gray mold rot on strawberries, late stage; *B*, leather rot on Aroma strawberry; *C*, longitudinal section of Aroma strawberry affected with the same disease; *D*, rhizoctonia brown rot on Missionary strawberry (color of rot partly masked by adhering soil); *E*, cross section of Missionary strawberry affected with the same disease; *F*, tan brown rot on Missionary strawberry; *G*, gray mold rot on green strawberry a short time after infection. (*B*, *C*, *D*, *E*, *F*, and *G*, from Dodge and Stevens (*11*).)

STRAWBERRIES

GRAY MOLD ROT

(*Botrytis* sp.)

Gray mold rot is one of the most serious diseases of strawberries and sometimes occurs on raspberries, blackberries, and dewberries. The disease is caused by a species of *Botrytis* apparently identical with the one that attacks grapes (pl. 9, *A*, *G*). The characteristics of that fungus and its relation to temperature and moisture conditions are given under Gray Mold Rot of Grapes (p. 8).

Blackberries, raspberries, and dewberries attacked by the fungus are soft and watery, whereas affected strawberries are firm and fairly dry superficially since in them there is no marked collapse of the tissues and little or no leakage of juice.

On strawberries, gray mold rot is most common in the cooler producing regions, where it sometimes causes a loss of 10 percent or more of the crop in the field. As noted under Grapes, it is especially favored by wet weather. In such weather the rot is worse in places where the leaf cover is heavy and conditions are particularly favorable for the growth of the fungus on flowers, flower stalks, fruitstalks, and various kinds of debris on the soil as well as on the fruit.

Raspberries, blackberries, and dewberries suffer very little from gray mold rot in the field apparently because they are borne singly or in small open clusters and not close to or on the ground like strawberries.

Gray mold rot attacks strawberries and other berries in transit and on the market, its development there depending on favorable conditions of moisture and temperature (p. 10). If berries affected with rot are allowed to remain in the packed fruit, they become centers of infection around which nests of rot may develop, as described for grapes (p. 8).

Probably very little can be done to control the rot in the field if conditions there favor its development. Control in transit depends on careful handling of the fruit to avoid bruises and skin breaks, careful culling wherever practicable to remove decaying fruits, and a temperature below 45° F., preferably about 40°. The culling is most effective when done in the field, because this practice avoids much of the bruising likely to occur if the culling is done in the packing shed.

Development of gray mold rot and other rots on the market can best be prevented by moving the fruit into consumption as quickly as possible (*8*, *11*, *14*, *29*, *31*, *33*, *36*, *37*, *38*, *39*, *40*, *43*, *46*, *50*).

LEATHER ROT

(*Phytophthora cactorum* (Leb. and Cohn) Schrt.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Leather rot is a fungus disease of strawberries that has been found in the field in Mississippi, Louisiana, Arkansas, Tennessee, Virginia, Maryland, Missouri, Illinois, and Kentucky and on the market in carlot shipments of strawberries from these States. It is most destructive in the Klondike and Aroma varieties.

Leather rot is characterized by a rather slight softening of affected tissues, by both external and internal discoloration, and by a marked

bitter taste. The tissues, however, become tough and leathery, so that the softening never even approximates the mushy, leaky condition produced by *Rhizopus*, nor the soft-spot condition produced by certain other molds. The discoloration, particularly on the outside, varies so greatly that it must be described in detail.

In the field, berries may be affected at all stages from blossoming to full maturity; the picture presented by each stage, if these are not chosen too close together, has characteristics which set it off from that presented by each of the others. In fruits that have barely begun to enlarge after petal fall, all parts become dark brown over affected areas, shading off into the natural green of the unaffected area around them; fruits mature enough to have turned red show, over affected areas, the same yellow to light brown at the center of the spot, but with a transition from this through darker brown to purple to the natural red of the berry; ripe, fully colored fruits sometimes show no color change at all except a slight darkening of the red over affected spots, or sometimes a faint tinge of the purple which forms the transition to red on less mature fruits (pl. 9, *B*).

On the market only the most advanced stages are seen. Here, however, a superficial growth of white mold, rare in the field, is frequently seen, and will serve as a diagnostic characteristic if taken in connection with the external color changes and the internal appearance.

In cross and longitudinal sections, strawberries affected by leather rot show a marked browning of the water-conducting system, accompanied usually by a less intense browning of all the other tissues (pl. 9, *C*). In very early stages this browning in the vessels is often the only visible symptom. So far as can be noticed by sight or by touch, affected tissues are not disintegrated, though they are always softened and become decidedly tough and leathery. At no time is there any clear line of demarcation between diseased and healthy flesh, nor can a separation of the two be made by mechanical means; it is not possible to lift or scoop out the part affected as can so easily be done with the rotten spots produced by *Rhizopus*.

CAUSAL FACTORS

Leather rot is caused by the fungus *Phytophthora cactorum*, an active parasite which is able to penetrate the uninjured skin of strawberry fruits. The disease has always been found associated with wet weather in the field and for that reason is known to growers as water soak. This use of the term implies a belief, often explicitly stated, that the berries take up too much water and become worthless. This probably does happen with some of the fruit during wet weather, for it is well known that strawberries produced during such weather are likely to be soft, succulent, and easily damaged even by the most careful handling. Moderately high temperatures are important also. In White County, Ark., during one rainy season when every rain was followed by a cool spell, leather rot was practically negligible, whereas during the corresponding season of the year before, also wet but much warmer, the rot cut down the marketable crop by fully 20 percent.

The factor of time must also be considered in dealing with this rot. Field observations have shown that with warm weather following heavy rains leather rot does not appear until about the third day after the

rain and does not reach a maximum until the fourth or fifth. If after a heavy rain there is dry weather for a week or more, the last traces of leather rot, in the field, may be expected to disappear by the seventh or eighth day.

CONTROL MEASURES

If shipments are precooled to a temperature between 35° and 40° F. and kept below 40° in transit there is very little danger that leather rot will cause appreciable loss during the ordinary transit time from southern shipping points to northern markets.

Observations made in Louisiana and Arkansas indicate that the rot can be controlled fairly well in the field by mulching, which keeps the berries from coming in contact with the soil (*11*, *30*, *31*).

RHIZOCTONIA ROT

(*Rhizoctonia* spp.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Rhizoctonia rot is known to occur in central Florida, North Carolina, Tennessee, and Arkansas. In rainy seasons strawberries from all these districts show this rot on the market, sometimes in such percentage that their market value is seriously reduced. All varieties grown where the rot occurs are susceptible.

Affected berries are usually one-sided and show a hard brown decayed spot to which small quantities of soil often adhere. Infection begins on the under side where the berry touches the soil, usually before it begins to turn red and sometimes before it is a third grown. Early infection results in deformed fruits, but since the rot develops slowly there may be no sign of it on the upper side of the berry. As a consequence it is difficult to keep affected fruit out of the pack (pl. 9, *D*, *E*).

Because of the slowness with which the rot develops there is little danger that it will spread from diseased to healthy fruit under good refrigeration (fruit temperature below 45° F.) in transit.

CAUSAL FACTORS

The rot is caused by an unidentified species of *Rhizoctonia*, a soil fungus, which is the cause of disease in a number of other plants. A study of artificially inoculated strawberries shows that infection takes place in the small pits in which the seeds (akenes) are embedded; it is not known whether the hyphae can penetrate the uninjured epidermis or are dependent on breaks in it for a way of entrance.

CONTROL MEASURES

Mulching with pine needles or straw is probably the best means of controlling this disease (*8*, *11*, *17*, *37*, *38*).

RHIZOPUS ROT

(*Rhizopus nigricans* Ehrenb. ex Fr.)

OCCURRENCE, SYMPTOMS, AND EFFECTS

The fungus *Rhizopus* has a wide distribution in nature and attacks many kinds of fruit. It is of most importance on berries, grapes, and

peaches; on strawberries, it frequently causes more loss than all other decay organisms combined.

On berries and grapes, *Rhizopus* causes a soft rot sometimes known as leak, the name having originated from the fact that the fungus, as it spreads through the fruit, breaks down the tissues and allows the juice to escape. In late stages there is almost always an odor of fermentation, but at no time does the fungus produce in berries and grapes the marked browning that is one of the symptoms of the rot in apples and peaches.

CAUSAL FACTORS

The cause of rhizopus rot of berries and grapes is here designated as *Rhizopus nigricans*, although the possibility is recognized that more than one variety or species of the genus is included under this name. Under ordinary conditions of moisture and temperature the fungus is characterized by a heavy growth of coarse white mycelium and small spherical spore-bearing heads (sporangia) that are white and glistening when young but which later become black and dull (pl. 10, *A*). In cold storage or under refrigeration in transit only a scant growth of mycelium is produced and the heads show as dense gray or black masses close against the fruit.

In warm wet weather, rhizopus rot is occasionally found on strawberries in the field; it sometimes occurs on mashed or overripe grapes, strawberries, and other fruits in the field or around the packing house. But such cases give no warrant for calling rhizopus rot a field disease; they are too unusual, too closely connected with special conditions. Most of the damage from this rot takes place in transit and storage though even there the mere occurrence of such damage is no proof that the fruit was generally diseased when it left the packing house. There may have been a few slightly decayed fruits in the packages, and a few so recently infected that they showed no discoloration or marked softening; it is more probable, however, that the fruit bore on its surface *Rhizopus* spores, which, because of conditions in storage or in transit favorable for spore germination and for growth of the fungus, started the rot at new places after the load was placed in the car or the storage room. Favorable conditions, of course, hasten the growth of the mold in fruits already attacked and its further spread to others lying near or touching them. Wet weather in the field favors the development of the disease in transit, by making the fruit more sappy, more easily bruised, and more susceptible to attack by the fungus.

The development and spread of rhizopus rot is greatly favored by water on the fruit, provided the temperature of the fruit is moderately high (p. 23). Investigations in a number of States have shown, however, that there is a distinct advantage in picking strawberries in the morning when they are cool even though they may be wet from rain or dew. Such berries are 15° to 20° cooler than those picked a few hours later, and when used in test shipments have always been found to arrive on the market much freer from rot.

The development and spread of rhizopus rot is also favored by skin breaks resulting from careless handling prior to loading or in transit, or from shifting and breakage due to improper stowing of the load. There may be some danger of loss from rhizopus rot when injuries are few, but it cannot be too often emphasized that the danger is much

A, Rhizopus rot on strawberries; *B*, powdery mildew on Alexandria (Muscat) grape; *C*, scarring on Malaga grape.

greater when they are many. Grapes which have been handled so carelessly that many of the individual fruits are cracked or even no more than loosened on the cap stem, and strawberries and other berries that have been bruised by careless picking or by being packed too high in the containers are much more susceptible to attack by *Rhizopus* than are fruits that have been carefully handled at all times.

CONTROL MEASURES

The danger of attack in transit by *Rhizopus*, therefore, is greatly increased by the presence of skin breaks and moisture; whether or not the attack takes place depends almost entirely on the temperature at which the fruit is held. For the species of *Rhizopus* (*R. nigricans*) which is most common in transit and on the market, the critical temperature or danger point is about 50° F.; 2° or 3° above this gives a chance for decay to begin; 2° or 3° below, the product is fairly safe. Delay in cooling, due either to failure to ice cars promptly or to loading of warm fruit, gives opportunity for the rot to develop and so increases the liability of loss; delay in moving the car also increases this probability, for by giving the fungus a longer time in which to work, it aggravates a condition that already exists, or causes one to arise that would not have done so had the car moved on time. For such perishable fruits as strawberries and other berries the importance of precooling immediately after the completion of loading into refrigerator cars is beyond question (*8*, *11*, *14*, *16*, *17*, *18*, *29*, *31*, *32*, *33*, *36*, *37*, *38*, *39*, *40*, *42*, *45*, *50*).

SCLEROTINIA ROT

(*Sclerotinia* sp., probably *S. libertiana* Fckl.)

Strawberries affected with sclerotinia rot are firm but rather watery and usually show small patches of a white, cottony, fungus growth that becomes quite luxuriant if the berries are held in a close moist place. If held in a dry place, the berries shrivel and the fungus growth collapses and finally develops hard, rounded black masses known as sclerotia or resting bodies.

The disease occurs in various sections of the South but is not often seen on the market. Losses caused by it are probably not large.

TAN BROWN ROT

(*Pezizella lythri* (Desm.) Shear and Dodge)

OCCURRENCE, SYMPTOMS, AND EFFECTS

Tan brown rot has been found in Cuba, Louisiana, Florida, Arkansas, Tennessee, Virginia, Maryland, Wisconsin, and Alaska. When field and transit conditions have been favorable for its development it also appears, sometimes in rather high percentage, on fruit shipped to the market.

The rot occurs on both green and ripe fruit as sunken, softened, tan-colored spots (pl. 8, *F*), which extend more deeply into the flesh of the berry than might be suspected from their superficial diameter. The rotted tissues are so thoroughly interpenetrated and held together by the fungus as to form a core that can easily be removed intact. The spots vary in diameter from about one-fourth to one-half inch, but

those seen on ripe fruit are usually the larger, partly because the fungus has had a longer time in which to grow and partly because development of the rot on ripe fruit is more rapid.

CAUSAL FACTORS

Tan brown rot is caused by the fungus *Pezizella lythri*, which has been known under a variety of other names. The fungus has three different stages and three different spore forms. In one or another of its stages it is found on about 50 different host plants widely distributed throughout North America and Europe and is also found in South America. It is a weak parasite that usually, perhaps always, is dependent on some injury for a way of entrance into the host. Development of the rot is favored by warm wet weather.

CONTROL MEASURES

Mulching with pine needles or straw is apparently the only method of controlling tan brown rot in the field. Control in transit and on the market depends on careful handling, temperatures below 45° F., and prompt movement of the shipments (*8*, *11*, *36*, *38*).

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